Report for 2002SD3B: Hydraulic Calibration of the Upper Soil Layers in a Glacial Till System

- Dissertations:
    - Kathol, John. 2003. Simulated corn yield responses in drained and undrained waterways. MS Thesis, Agricultural and Biosystems Engineering. South Dakota State University, Brookings, South Dakota.

Report Follows:

Problem and Research Objectives:

Soils derived from glacial till are common in the northern Corn Belt and northern Great Plains. In the Dakotas, there are nearly 19 million ha of farm land east of the Missouri River with till-derived soils. Many of these soils derived from till are among the most productive agricultural soils for crops such as corn and soybean.

The mechanism of water redistribution is poorly understood for loess-capped soils with lower layers derived from glacial till. There are three potential mechanisms for water movement to areas lower in the landscape: overland flow as runoff/runon, downward flux then lateral movement at the top of the unsaturated weathered till, and downward then lateral movement within the saturated weathered till. Subsurface water movement remains the most poorly defined. This project focused on the movement of water downward through the upper soil layers.

The results of the field research proposed in this project will be used to validate and improve water flow models currently used for assisting in the definition of yield goals. The growth and yield portions of these models generally perform adequately but the water flow submodels are not yet sufficient to simulate water flow with enough accuracy and precision to estimate the correct amount of water stress experienced by the crop.

Methodology:

The two field sites were located near the top of a hill but not at the crest, in a nearly level area. The soil surface was modified slightly so that the flooded surface was nearly level. The 2001 site was located in the NE ¼ of the SE ¼ of Section 19, R48W, T109N on a Kranzburg soil The 2002 site was in SE ¼ of the SW ¼, Section 18, R48W, T107N on a Houdek clay loam soil. The hydraulic properties at each site were measured using the instantaneous profile method, as described below.

A frame of 50 mm by 300 mm lumber was placed around the flooded area to prevent overland flow (runoff). The frame was inserted (trenched) into the soil about 100 mm to prevent near-surface lateral water movement.

Water was introduced by flooding the soil surface within the frame. An additional area surrounding the framed area was also flooded. This additional flooded area served as a buffer so that measured flow from the interior framed area was vertical. After flooding was complete, the plot area was covered with plastic to prevent evaporation from the soil surface.

During and after flooding, soil matric potentials were measured with tensiometers. The matric potentials and instrument elevations were used to calculate hydraulic gradients. Within the flooded framed area, matric potentials were measured at three depths: 450, 750, and 1050 mm below the soil surface. Matric potential measurements at each depth were replicated four times. Soil water content was measured with the neutron probe in 150 mm intervals to a depth of 1.05 m. The neutron probe measurements were replicated four times.

The plots were flooded on 24 October 2001 and 21 October 2002. Monitoring took place until 21 November 2001 and 26 November 2002. In 2002, an early freeze rendered the tensiometers useless nearly immediately after the flooding took place. In 2001, the tensiometers were operated for the entire monitoring period. In each year, the access tubes and the remainder of the equipment in the plots were removed and monitoring ceased one or two days before the first major (>20 mm) snow fall of the season.

Principal Findings and Significance:

Drainage rates from the plots were small for the relatively short monitoring periods at both sites (Figs. 1 and 2). The 2002 matric potential data are not shown because of the cold weather immediately after water application that caused immediate failure of the tensiometers. The measured water contents and matric potentials show steady but slow drainage of water from each plot after the initial flooding. The lower depths in 2002 show little change of water content but the upper layers were decreasing in water content (Fig. 2). Because the drainage rate at the site in 2001 was small and relatively constant, a single value of hydraulic conductivity was calculated at that site. That value was 2.0 mm per day. The average volumetric water content at the 1.05 m depth corresponding to that value of K was 0.330 m/m (or 33.0%).

The soils at the Kranzburg site measured in 2001 apparently increase in clay content with depth. The water content increases with depth (Fig. 1), indicating a greater clay content with a greater water holding capacity. The change of soil clay content (and stored water) with depth is very small at the Houdek (2002) site.

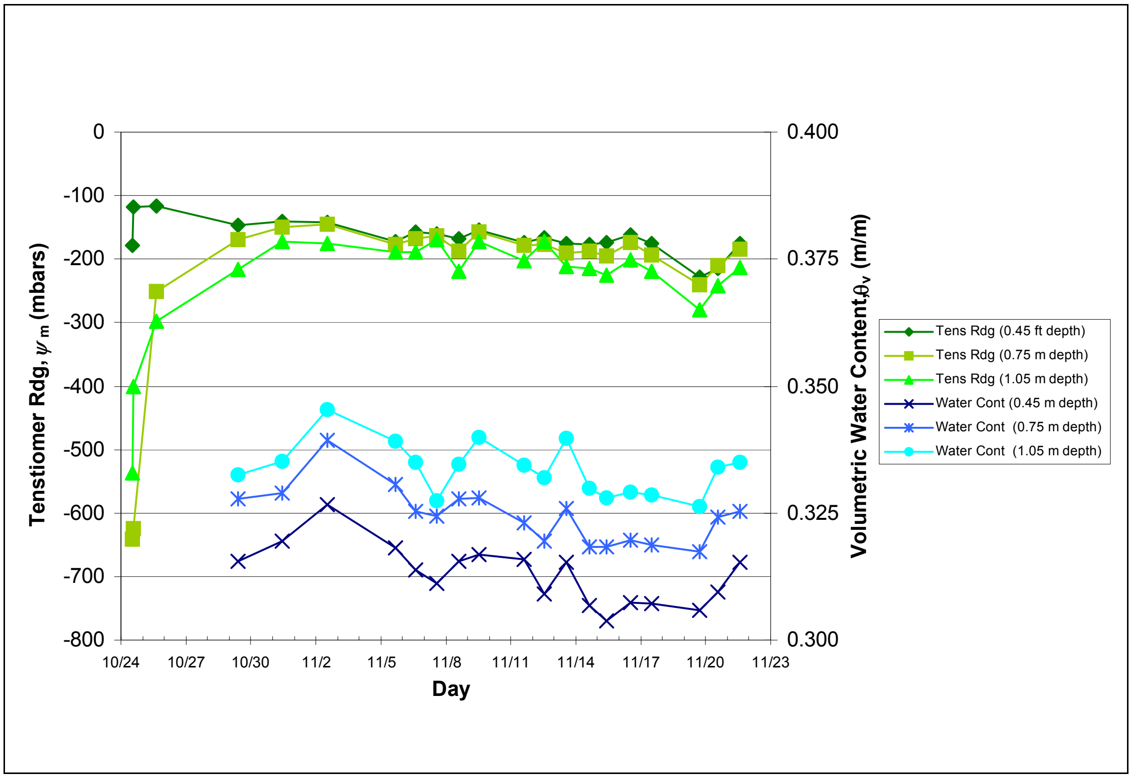

Figure 1. Matric potential and water content during the test in 2001.

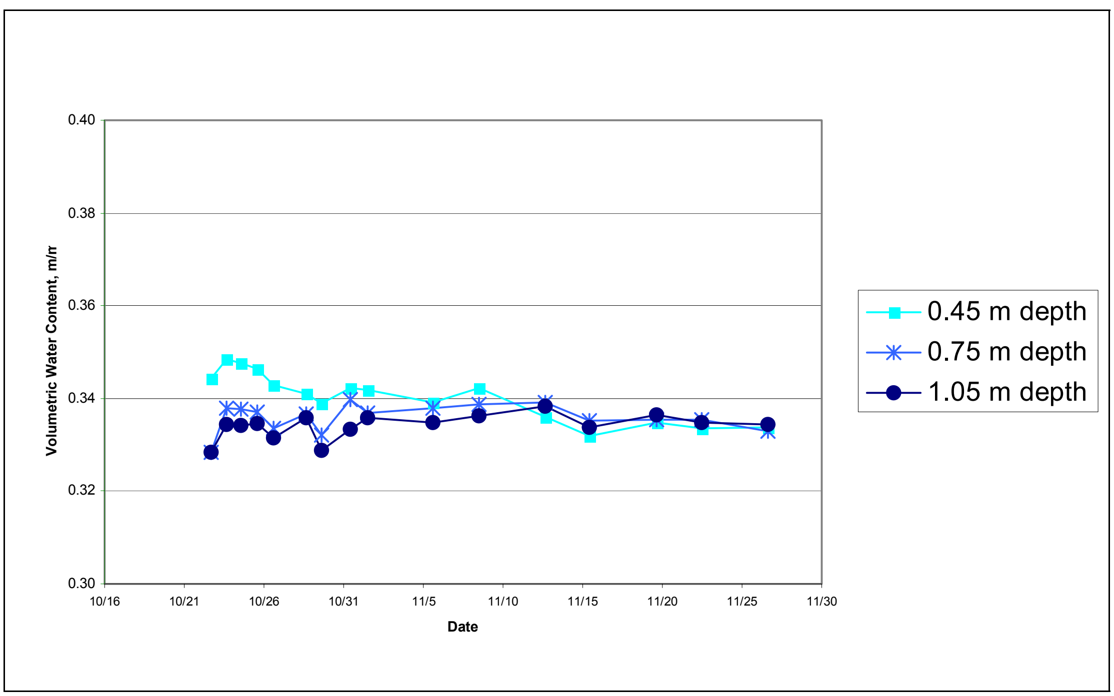

Figure 2. Water content during the test in 2002.

The vertical drainage rates at the two sites were calculated as the change of water content in the top 1.05 m of the soil profile over the entire monitoring period. The average drainage rate in 2001 was 0.48 mm per day and the average in 2002 was 0.27 mm per day. The drainage rate for various depths was also calculated using the 2002 data. The slope of the regression line (stored water regressed by date) is the drainage rate. The drainage rates varied from 0.15 mm per day (for the top 0.45 m of the soil profile) to 0.27 mm per day (0.75 and 1.05 m depths). The R^2 values for all regressions were high (between 0.66 and 0.85).

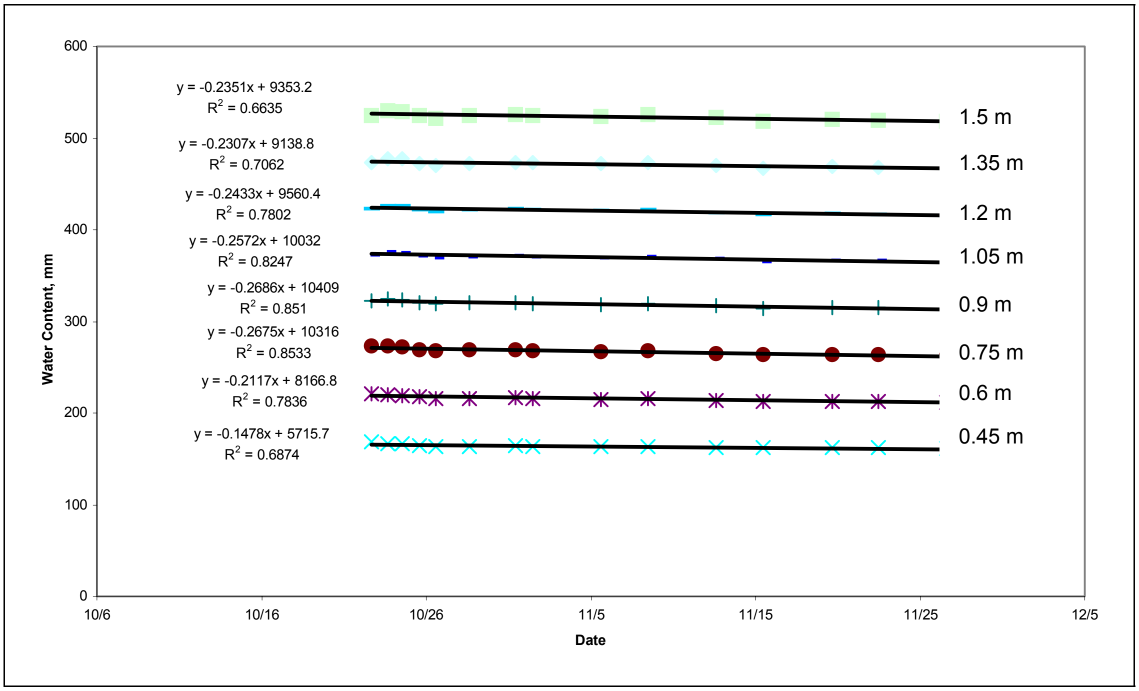

Figure 3. Drainage rate by depth at the Houdek (2002) site.

The instantaneous profile method is accurate and valuable but labor- and land-intensive. Therefore, testing of a single plot for a short time period would have value if the small data set could be extended in some manner. The instantaneous profile method was used to measure soil hydraulic properties of 36 plots during a 4-month period (Trooien and Reichman, 1990). That 4-month study took place in North Dakota at a site with till-derived soils similar to those used in this study. The single measurement of K from each site in this study can be compared to the K-water content function measured in the North Dakota study to compare the hydraulic properties of the three sites. The flooding took place during a period of nearly two months in North Dakota and resulted in water contents much greater than those measured in the current study (Fig. 3). Plotting the K value from 2001 in the current study shows that it fits reasonably well with the curve measured in the North Dakota study (Fig. 3).

The final drainage rate measured in the North Dakota study was 0.6 mm per day, which is similar to the drainage rate measured in 2001. While the drainage rate in 2001 was 0.48

mm per day, which is slightly less than the North Dakota clue of 0.6 mm per day, the water content in 2001 was also less than the water content in the ND study (Fig. 3), so you would expect to measure a lesser drainage rate.

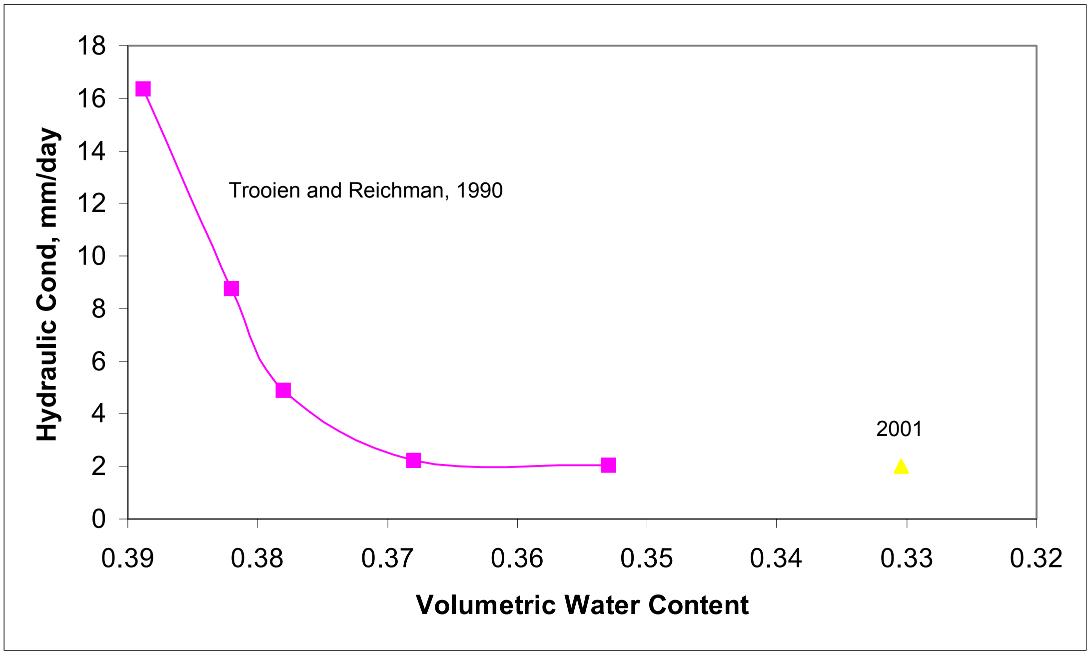

Figure 4. K(theta) function from Trooien and Reichman (1990) and from the Kranzburg (2001) site in this study.